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Noise on the AC power input to a computer power supply can cause problems in a computer or other piece of equipment. Often a UPS is proposed as a solution to prevent these noise problems.

**Common-mode and Normal-mode Noise**

In a simple AC power distribution system, there are usually three wires in the cord connecting a computer to the wall socket. There is an active or live wire (also known as the hot wire), a neutral wire and a ground wire. Power is delivered to the load using the active and neutral wires. The ground wire is for safety purposes.

In the context of power supplies, noise is any undesirable voltage impulse which appears at the output. Noise at the output is caused by noise on the three input wires and may appear as either "common-mode" or "normal-mode."

**Common-mode** noise is present on both the active and neutral wires and is measured with respect to ground. (The term "common" refers to the fact that identical noise appears on both the active and neutral wires.) Incorrectly, however, common-mode noise is understood to be only on the neutral wire. Common-mode noise can be created by lightning, the switching of circuit breakers or poor grounding. The use of surge protectors can also create common-mode noise as the energy from the normal-mode noise is diverted into the neutral wire.

Noise which can be measured between the active and neutral wire is called **normal-mode** and is sometimes referred to as **differential-mode** or **transverse-mode** noise. Most normal-mode noise are created as a result of large loads switching on or off, particularly big motors and power factor correction capacitors.

**How Noise Affects A Computer Power Supply**

In order for noise to damage computer hardware or interfere with data processing, a path within the computer must be available to dissipate the impulse energy. Virtually all modern computers are powered by a **switch-mode power supply (SMPS)**. SMPS by design provides a conduction path to dissipate the energy from the impulse making the computer susceptible to damage.

**A SMPS Subjected To Normal-mode Noise**

Normal-mode noise attempts to dissipate its energy along any path from line to neutral. If the normal-mode noise has sufficient voltage (or energy), damage could first occur to the SMPS and then to the computer circuitry. The p-n junctions of the rectifier diodes can breakdown due to excessive reversed biasing. The capacitors may degrade if the noise is opposite in polarity or exceeds operating limits. Transformer insulation may breakdown if the noise peaks are excessively high.

However, components such as rectifier diodes, filter capacitors and the transformer require large amounts of energy to be damaged. Thus, normal-mode noise is normally not a threat to computer equipment and it is also much more likely that the SMPS will be damaged before any damage occurs to the computer hardware. Nevertheless, it is possible for normal-mode noise to damage the computer hardware.

**A SMPS Subjected To Common-mode Noise**

Common-mode noise poses a greater threat because the noise attempts to dissipate its energy from neutral to ground or from active to ground. In order for damage to occur, a path must exist for the current to flow and two paths are possible through the SMPS.

Common-mode noise may be coupled through the high frequency transformer or along paths that have parasitic or stray capacitance. Firstly, since common-mode noise generally consists of high frequency impulses, there is a high probability that the noise will see the high frequency transformer just as a

coupling capacitor and pass through unobstructed. And secondly, more stray capacitance paths may exist within SMPS simply because they are smaller in physical size and more densely packaged as compared to other types of power supplies.

If common-mode noise does find its path through the SMPS, the noise voltage would likely appear between the logic ground (also known as the common reference) and the voltage-supply pins of the computer electronics. If this noise voltage exceeds the maximum voltage specification of a semiconductor, the energy from the noise will pass through the logic hardware to ground, dissipating its energy along the way. The result is reduced reliability, interference to data processing and possibly permanent damage. As semiconductor integrated circuits (IC) can only withstand a few volts, these components can only tolerate currents of a few tens of milliamperes. Therefore, the magnitude of the common-mode noise does not need to be high to cause damage.

### **Possible Solutions to Normal-mode Noise**

Surge suppressers and protectors are available to address the problems caused by normal-mode noise. These devices are connected between the active and neutral wires at the power outlet. Most surge suppressers contain a device called a metal oxide varistor (MOV) which performs voltage suppression. A MOV is a device whose resistance value is dependent on the voltage across its terminals. A high voltage which appears across a MOV is clamped to a specified voltage and the current is diverted through the MOV and away from the sensitive computer equipment.

Surge suppressers, however, can create an additional problem. The current which is diverted through to the neutral wire can create common-mode noise. The peak voltage of the common-mode noise depends on the impedance of the power leads, the magnitude of the original current and the energy dissipation capacity of the surge suppresser.

There also exist complex hybrid forms of surge suppressers on the market which divert the noise current and energy in a similar manner. These hybrid surge suppressers contain additional filtering and clamping components such as inductors (chokes), capacitors and zener diodes. In some configurations, the MOVs and filters may be connected across the neutral and ground wires to reduce any common-mode noise created from the action of the suppresser. Because common-mode noise can be created and because it poses a greater threat to computer equipment, the use of surge suppressers often must incorporate some form of additional common-mode noise protection.

### **Possible Solutions to Common-mode Noise**

Common-mode noise poses a greater threat compared to normal-mode noise because of the different path taken to dissipate the noise energy. Potentially damaging common-mode noise can be much less in magnitude than a normal-mode impulse.

Fortunately there are products available to eliminate common-mode noise. The best way to eliminate noise, including common-mode and normal-mode types, is to use a true On-Line UPS. Because a true On-Line UPS uses double conversion technology, the UPS output is well isolated from any noise that might appear at its input.

An (isolation) transformer can also be very an effective means to reduce or eliminate common-mode noise. The transformer naturally filters common-mode noise and the Faraday shield between the windings filters high frequency normal-mode noise. The drawback with using a transformer is that it is big, heavy, noisy, expensive and often unnecessary if a true On-Line UPS is being used.

With all transformers, stray capacitance, called inter-winding capacitance, can exist between the windings. It is via this inter-winding capacitance that high frequency noise can couple through to the secondary winding. However, when a grounded shield is used to separate the primary and the secondary windings, the inter-winding capacitance is significantly reduced. This effectively increases the impedance (resistance) of the coupling path and therefore significantly reduces the amount of high frequency noise that can couple through to the secondary winding. In general, a shielded and isolated transformer will

exhibit an attenuation factor of about -60dB, which is a 1000 to 1 ratio. This will mean that a 1000-volt impulse will appear on the secondary winding as a 1-volt impulse.

In the context of protecting computer equipment, a UPS has a distinct advantage over other solutions simply because it can power the equipment during a blackout (total power loss). All UPS configurations also have surge protection and some configurations even have power conditioners built-in, so additional protection equipment is not required. More specifically, a true On-Line UPS configuration is more effective than other configurations because the power is constantly conditioned before it is supplied to the load.

### **How Effective is the Protection?**

To be able to compare the noise reduction performance or the effectiveness of the power conditioning solutions on the market, consumers must be able to understand and interpret the product performance specifications presented by the manufacturers. There are two main terms to examine.

The first is a term called **common-mode noise rejection (CMNR)**. It measures the ability of a device in reducing common-mode noise. CMNR is defined as the magnitude of the normal-mode noise output due to the input common-mode noise divided by the magnitude of the incoming common-mode noise.

The second term that the reader needs to be aware of is the **normal-mode noise rejection (NMNR)** which is also called transverse-mode noise reduction (TMNR). The NMNR value describes the ability of a device to reject normal-mode noise. NMNR is defined as the magnitude of the normal-mode noise output divided by the magnitude of the normal-mode noise input.

Both CMNR and NMNR are functions of frequency so to really understand the noise reduction capability of a transformer, filter or UPS, a plot of attenuation versus frequency is necessary. Most equipment is specified at a single frequency, usually where the attenuation is the best,